Cell Cycle & Cell division

* All organism start their life as → a single cell.
* Characteristics of cell (indeed of all living org) → Growth, Reproduction

CELL CYCLE

During the division of cell → DNA replication, Cell growth take place

* All the processes (cell division, DNA replication, Cell growth) have to take place in a co-ordinated way
  - to ensure correct division
  - Form of progeny cells containing intact genomes
  - ⊙ Sequence of events by which cell duplicates its genome
  - synthesizes other constituents of the cell & eventually divides into 2 daughter cells → CELL CYCLE

Cell growth (in terms of cytoplasmic increase) → continuous

DNA replication (synthesis) → only one specific stage in cell cycle.

Replicated chromosomes (DNA) then distributed to daughter nuclei by a complex series of events during cell division

* These events are under → Genetic control.

Phases Of Cell cycle

* Typical eukaryotic cell illustrated by human culture cells
  - these divide ≈ 24 hrs (every)
* Duration of cell cycle vary from
  1. organism to organism
  2. cell type to cell type
* YEAST cell cycle → 90 min

Cell cycle divided into 2 phases. (Basic)

INTERPHASE → Resting phase

- Phase b/w 2 successive M-phase
- Lasts more than 95% of duration.
- Cell is preparing for division by undergoing
  1. cell growth
  2. DNA replication

  in orderly manner.

M Phase (Mitosis phase)

(cell division proper)

- Actual division / Mitosis
- about an hr (≈ 1 hr)
- starts with → nuclear division (KARYOKINESIS) separation of daughter chromosome corresponding to
- usually ends into → (CYTOKINESIS) division of cytoplasm

FINAL STAGE ... divided into

G_1

① Interval b/w mitosis & initiation of DNA replication

② Metabolically active cell

③ Grows continuously.

④ Carry out normal metabolism

* Cell grows
* Most of the organelle duplication

S

Synthesis

① DNA replication or synthesis takes place

② Amount of DNA doubles per cell.
2C → 4C

③ No change in chromosome number.

In ANIMAL cell
- DNA replication → in nucleus
- Centriole duplication → in cytoplasm

Histones

G_2

① Proteins are synthesized

② Cell growth continues

* Period of cytoplasmic growth.

* Most dramatic period of cell
* Involves → major reorganisation of virtually all the components of cell.

* EQUATIONAL DIVISION → no. of chromosomes remain same.
* Cell division is progressive
  - b/w various stages. cannot be drawn
  - Very clear cut division

④ phases : PMAT

PROPHASE

1st stage of mitosis.

* Follows S, G_2 → phases

In S & G_2 phase → new DNA molecules are ① Distinct ② Intermixed

Prophase is marked by initiation of condensation of chromosomal material.

chromosomal material becomes untangled during Chromatin Condensation

Duplicated centrosome begins to move towards opposite poles

* Completion of prophase is marked by at end

Chromosome material	chromosome	Each centrosome	viewed under microscope
condenses to form compact mitotic chromosome	seen as 2 chromatids attached at centromere	radiates out Microtubule (asters)	do not form ① Golgi ② ER ③ nucleolus ④ nuclear envelope

2 asters + spindle fibres → mitotic apparatus

* Spindle fibres start appearing

(*) Some cells in Adult animals → do not exhibit cell division eg heart cell

(*) Many other cells divide occasionally as needed to replace cells that have been lost bcz of injury → cell death

These cells do not divide → EXIT G_1 phase & enter a quiescent stage (G_0) called inactive stage

- metabolically active
- No longer proliferate unless called on to do so depending on requirement of organism.

In ANIMALS

- mitosis → seen in diploid somatic cell.
- Exception → Honey bees → haploid cells also divide by mitosis

In PLANTS

mitotic division seen in both Haploid cells. Diploid cells.

METAPHASE

Chromosomes are spread through cytoplasm

Complete disintegration of nuclear envelope marks start of this phase

By this stage → Condensation of chromosome is completed

Chromosome can be observed clearly under microscope

Date / / Page

(*) At this stage → MORPHOLOGY can clearly be studied

Metaphase chromosomes made of 2 sister chromatids held together at centromere

(*) Small disc shaped structures at the surface of Centromere are called Kinetochores

These structures serve as site of attachment of chromosome to the spindle fibres that are moved into position at the centre of cell.

* Metaphase is characterised by → All chromosomes coming to lie at equator with one chromatid of each chromosomes connected by its kinetochore to spindle fibres from one pole

& its sister chromatid → other pole

* The plane of alignment of chromosome at metaphase → Metaphase plate

Key features of metaphase

- Spindle fibre attatch to kinetochore of chromosome
- Chromosomes are moved to spindle equator & got aligned along metaphase plate through spindle fibres to both poles.

ANAPHASE

(*) Onset of this phase → each chromosome split simultaneously & 2 daughter chromatids

(*) As each chromosome moves away → Centromere directed towards pole (hence at leading edge)

Referred as daughter chromosome of future daughter nuclei begin migration towards 2 opposite poles.

With arms of chromosome trailing behind

(*) Anaphase characterised by

Centromere split → chromatid separate	Chromatids move towards opposite poles.

TELOPHASE

Date

* At beginning of this stage → Chromosome have reached respective poles → decondense, individuality lost → individual chromosome can No longer be seen

Key Events → Reformation of Golgi, ER, Nucleolus; Nuclear envelope develops around chromosome cluster at each pole forms 2 daughter nuclei; Chromosome cluster at opposite spindle poles as their identity lost discrete elements

collect at each of 2 poles ← tends to ← each set of chromatin material

Cytokinesis

Accomplishes: ① karyokinesis ② cytokinesis at the end cell division completes.

ANIMAL CELL

Appearence of furrow in the plasma membrane.

① Furrow deepens
② Ultimately joins in centre

PLANT CELL

enclosed by relatively inextensible cell wale.

therefore undergo cytokinesis by → Wall formation

starts in centre & grows outward to meet existing lateral walls

Precursor of new cell wale → cell plate → represents → middle lamella b/w the walls of 2 adjacent cells

During cytokinesis, organelles like Mitochondria, Plastids get distributed b/w 2 daughter cells

* In some organism, Karyokinesis followed cytokineses results → formation of syncytium (liq. endosperm in coconut)

SIGNIFICANCE OF MITOSIS

results in → production of diploid daughter cells with identical genetic complement.

* Growth of multicellular organism due to → mitosis
* Mitosis = cell repair
  - upper layer of epidermis
  - cells lining the gut
  - Blood cells

There can be no cell division without DNA replication

Some lower plants → Pteridophyte, Chlamyd., Spirogyra
social insects → honey bee
→ haploid cells divide by mitosis

Haploid cells in higher plants where cell div. doesn't occur — microspore, megaspore

* Mitotic divisions in meristematic tissue
  - apical cambium
  - lateral cambium

results in continuous growth of throughout life

Cell growth disturbs nucleo-cytoplasmic ratio.

To restore it → mitosis occurs

MEIOSIS

- Prod. by sexual Reprod. → includes fusion of 2 gametes (each with * complete haploid set of chromosomes)
- Gametes are formed by → Specialised diploid cell
- Specialised kind of cell division → reduces the chromosome no. by half. → results in prod. of haploid daughter cells.

* Meiosis ensures → prod. of haploid phase in life cycle of sexually reproducing organisms
* Fertilization restores → diploid phase.
* We come across meiosis during gametogenesis → in plants, animals

KEY FEATURES OF MEIOSIS

- involves → 2 sequential cycle of nuclear division called Meiosis-I, cell division called Meiosis-II. BUT single cycle of DNA replication.
- initiated after → Parental chromosomes have replicated to produce identical sister chromatids ↓ at S-phase.
- involves → ★ Pairing of homologous chromosomes & ★ Recombination b/w non-sister chromatids of homologous chromosomes.
- 4 haploid cells are formed at the end.

MEIOSIS-I

① PROPHASE I : Typically longer & complex than → mitotic prophase. * Long stage

Relatively short lived stages than ↓

LEPTOTENE

* Chromosomes become gradually visible under a LIGHT MICROSCOPE.
* Compaction of chromosome continues throughout this stage.
* Complex formed by a pair of synapsed homologous chromosome called BIVALENT / TETRAD → More clearly visible in next stage pachytene.

ZYGOTENE

* Chromosome starts pairing. This process of association is called SYNAPSIS
* Such paired chromosomes ↓ Homologous chromosome.
* ELECTRON MICROGRAPHS of this stage indicate that synapsis is accompanied by formation of complex structure called SYNAPTONEMAL COMPLEX.

PACHYTENE

* 4 chromatids of each bivalent chromosomes become distinct & clearly appear as TETRAD.
* This stage characterised by ↓ Appearence of recombination nodules ↓ sites at which CROSSING OVER occurs b/w non sister chromatids of homologous chromosome.
* CROSSING OVER is exchange of genetic material b/w two homologous chromosomes.
* CROSSING OVER is enzyme mediated process.
* Enzyme involved ↓ RECOMBINASE
* Crossing over leads to ↓ Recombination of genetic material on the 2 chromos.
* Recombination completed at end of this stage. ↓ leaving chromosome linked at the site of crossing over.

DIPLOTENE

* Recognized by dissolution of synaptonemal complex. & Tendency of recombined homologous chromosomes to separate except at the site of crossing over.
* X shaped structures are called ↓ CHIASMATA
* In oocyte of some vertebrates ↓ diplotene can last for MONTHS or YEARS

FINAL STAGE — DIAKINESIS

DIAKINESIS represents transition to METAPHASE.

* Marked by — Terminalisation of chiasmata
* chromosomes — fully condensed.
* Meiotic spindle — assembled to prepare homologous chromosome for separation
* By the end of this stage — Nucleolus disappear, Nuclear envelope breakdown.

MEIOTIC SPINDLE

METAPHASE - I

* Bivalent chromosomes — align on equatorial plate
* Microtubules — from → opposite poles of Spindle — attach to → Kinetochore of homologous chromosome.

ANAPHASE - I

→ HOMOLOGOUS CHROMOSOMES separate.

→ SISTER CHROMATIDS — remain associated at their centromeres.

TELOPHASE - I

→ • Nucleolus, • Nuclear membrane → reappear. → CYTOKINESIS followed resulting in DYAD OF CELLS.

* ALTHOUGH IN MANY CASES → Chromosomes do undergo some dispersion, they do not reach extremely extended state of interphase nucleus

* THE STAGE b/w 2 meiotic divisions — is called → INTERKINESIS (generally short lived)

* NO DNA REPLICATION IN INTERKINESIS

* INTERKINESIS is followed by prophase - II (much simpler than prophase - I)

MEIOSIS - II

→ initiated immediately after cytokinesis usually before chromosomes have fully elongated.

→ Resembles — NORMAL MITOSIS

Prophase - II

- Nuclear membrane disappears by the end of this stage.
- Chromosomes again become compact.

METAPHASE - II

* Chromosomes align at the equator.
* Microtubules from opposite poles of the spindle get attached to Kinetochores of sister chromatids.

ANAPHASE - II

* Begins with - simultaneous splitting of the centromeres of each chromosome.
* Move towards opposite poles by shortening of microtubules attached to kinetochores.

TELOPHASE - II

* 2 groups of chromosome get enclosed by nuclear envelope.
* Followed by CYTOKINESIS resulting in TETRAD OF CELLS (4 haploid daughter cells)

SIGNIFICANCE OF MEIOSIS

* Conservation of specific chromosome no. of each species achieved across generations in sexually reproducing organisms.
* Even though process, per se, paradoxically results in reduction in chromosome no by half.
* It increases genetic variability in population of organism from one generation to the next.
* VARIATIONS very important for process of EVOLUTION.